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THERMOPLASTICS COMPOSITES VS. THERMOSET COMPOSITES

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Abstract

The possibility of property enhancement through fiber reinforcement is among the key factors that make plastics an attractive candidate for new engineering materials. Both thermoplastics and thermosets can gain the benefit of fiber reinforcement whereby various systems have been developed to offer flexibility of choice to designers and manufacturers. The aim of this paper is therefore to briefly review the advantages and the limitations of thermoplastic and thermoset composites in terms of material properties and processing characteristic.

Introduction

A composite is the combination of reinforcement material, i.e. a particle or fiber, in a matrix or binder material which may be either a thermoset or a thermoplastic. The materials act in concert - one helping the other. Fiber reinforced plastics or FRP are a subdivision of composites group in which the matrix is a polymer (or plastics) and the reinforcement is always a fiber.The major reinforcements currently used are based on glass, carbon and aromatic polyamides (aramids).

In general, the matrix has a lower strength compared to the fiber which is also stiffer as well as more brittle. Reinforcement is primarily used to strengthen the matrix system i.e. to improve the mechanical properties of the matrix and to provide a usable product. To gain maximum benefit from the reinforcement, the fibers should support as much applied load as possible. The bond between the fiber and the matrix is the crucial part of the composite structure. The function of the matrix is to support the fibers and to transmit the external applied stress to the fibers by shear at the fiber-matrix interface.

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Material characteristics

Thermosetting materials are those that undergo irreversible changes under application of heat through the formation of crosslink network. The final product is stable to heat and cannot be made to melt or flow. Thermoplastics are materials which can be taken through heating and solidification cycles. They can be made to flow and take on new shapes when heat and force are applied.

Thermoplastic matrices have the advantage of rapid processing to mass produce complex shaped articles, i.e. materials can be injection molded. Thermosetting matrices are preferred for highly reinforced (complex shaped and huge) structures fabricated by hand lay-up technique because of the ease with which the fibers can be wetted at the low viscosity, pre-polymer stage.

The choice: thermoplastic or thermoset?

In comparing the options of thermoplastic and thermosetting resins, there are three areas where a manufacturer may want to consider, namely; quality, processing and performance.

With thermoplastic resins, the fabricator has enhanced quality assurance because he needs not worry over the storage of the unused resins and the chemistry of the reaction. With thermosets, the materials producer may have to take into account the thermoset chemistry and the problem of the resin polymerizing in the storage drum, i.e. gelation.

With thermoplastic materials the low level of fiber wetting and difficulty in achieving a uniform fiber distribution limits the application of this family to lightly loaded structures. The low fiber volume fractions and short fibers inevitably limit the stiffness and strength of the composites, and hence limit their use as high performance materials. But what they lack in certain aspects, they make up for it in other areas. Thermoplastics composites offer high rate processibility and design flexibility.

Since manufacturing of thermoplastics involves normally heat and shaping, rapid processing is possible. The components can even be subjected to subsequent shaping operations paving a path to tailoring structures to shape and with feasibility for repair work. The scrap materials can also be reclaimed. The commercial concern for profit-making which puts an emphasis on rapid low cost processing tends to exclude the majority of thermoset processing techniques.

For thermosets, the extensive dependence on labor-intensive hand lay-up procedures precludes their wider applications in general engineering. Only in cases of chopped fiber materials, such as sheet molding compound (SMC) can items be produced in volume. Nevertheless, even this is being held back by the material property limitations and the problems of handling unstable intermediate materials. Compression molding and resin transfer molding (RTM) are possible exceptions. Thermoset composites are therefore often regarded as a specialty business.

Enhanced service performance of thermoplastic composites is available through the toughness of linear chain thermoplastics such as PEEK. The semi-crystalline polymers allow the thermoplastic composites to be tailored to resist certain aggressive environments. Although they have potential for low cost processing and performance, there are also some limitations of the thermoplastic materials. In general, the glass transitions are lower in thermoplastic polymers than in thermosets. This effectively limits the load carrying capacity of the former. The absence of crosslinking in thermoplastic matrices also makes them relatively less stiff and more prone to creep than their thermosetting counterparts. Since thermoplastics are processed in the molten stage, the high melt viscosity in comparison to the thermosetting pre-polymers makes the fiber impregnation stages more difficult. The stiffness of thermoplastic prepregs and the absence of tack may create problems when fabricating complex curvatures. In addition, the relative chemical inertness of fully polymerized thermoplastic polymers can present difficulties in achieving good adhesion at the fiber-matrix interface. The fabrication operations thus may call for carefully controlled chemistry.

Conclusion

With this list of advantages and limitations, thermoplastic and thermosetting matrix systems offer the composite industry a spectrum of choice which gives the opportunity for further expansion of the industry as a whole.

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